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US ARMY ELECTRONICS RESEARCH & DEVELOPMENT ACTIVITY

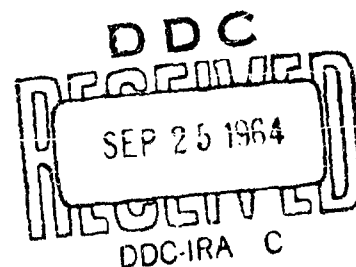
EDDY SHED HOT WIRE ANEMOMETER

By

ROY I. GLASS, JR.

ERDA-185

SEPTEMBER 1964



**WHITE SANDS MISSILE RANGE
NEW MEXICO**

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ENVIRONMENTAL SCIENCES DIRECTORATE
U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT ACTIVITY
WHITE SANDS MISSILE RANGE
NEW MEXICO

ABSTRACT

This paper discusses the need for an accurate low wind speed measuring system for the White Sands Missile Range Wind Instrument Test Facility. It describes a device that has been installed in the facility and which operates on the principle of periodic eddy shedding on the down-wind side of a cylinder. Also presented is the special readout system developed for the device.

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INTRODUCTION

Wind tunnels designed for low-speed operation in the ranges below 80 miles per hour are used for the calibration and testing of wind-measuring equipment. A tunnel of this type is in use at White Sands Missile Range (WSMR), New Mexico.

Facilities for this application have certain stringent requirements relative to the precision of the tunnel wind velocity control and measurement. This is particularly true for wind speeds in the range of 10 miles per hour and less. The WSMR system utilizes a combination of impeller pitch and speed control to achieve incremental adjustment capabilities of approximately 0.1 mile per hour in this critical range. The instrument which has been found to measure the wind speed most accurately at these values is the eddy shed hot wire anemometer.

DISCUSSION

The eddy shed hot wire anemometer is based on the Von Karman vortex street principle, which states, in essence, that when a cylindrical object is placed in an air stream of parallel flow, there will be developed, in the down-wind wake of the cylinder, periodic fluctuations or eddys (Figure 1). These periodic eddys have a frequency which is dependent on the diameter of the cylinder and the wind velocity according to the relationship:

$$\text{Frequency} = \frac{\gamma}{d^2} \left(0.212 \frac{Ud}{\gamma} \pm 4.5 \right)$$

where γ = flow viscosity (Nominal value taken as 1.62×10^{-4} ft²/sec)

d = cylinder diameter in feet

U = wind velocity in fps

$\frac{Ud}{\gamma}$ = Reynolds number.

This holds for Reynolds numbers between 50 and 150. It is interesting to note that the frequency is independent of changes in wire characteristics. Frequency variations with wind velocity for four different cylinder diameters (.1233, .065, .032, and .020 inch) are shown in Figures 2, 3, 4, and 5.

Since these eddy frequencies follow such a close relationship to wind velocity, they offer a very accurate means of measuring air flow in the wind tunnel. The critical lower wind speeds are in the range in which the eddy shed cylinders offer optimum operation.

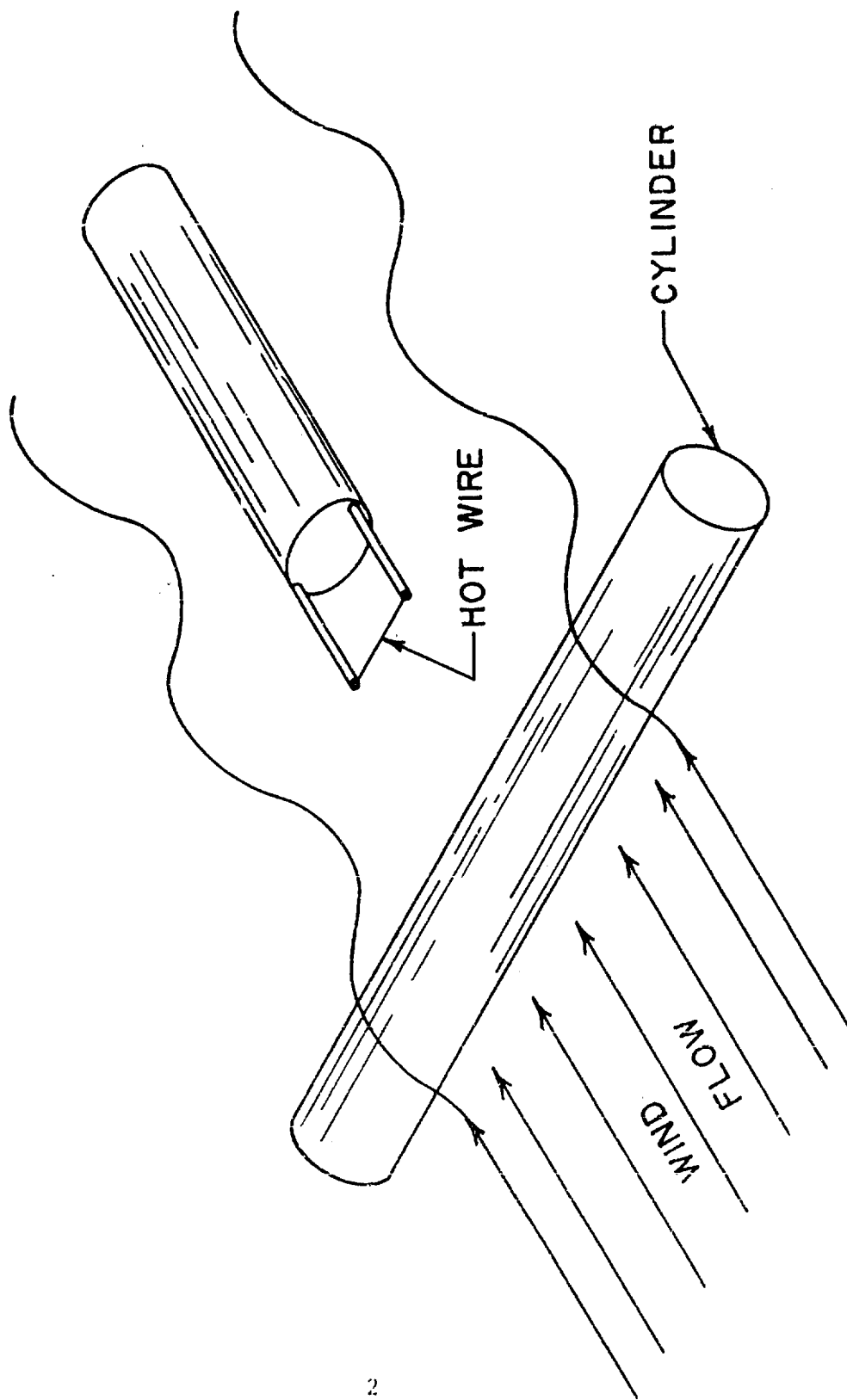
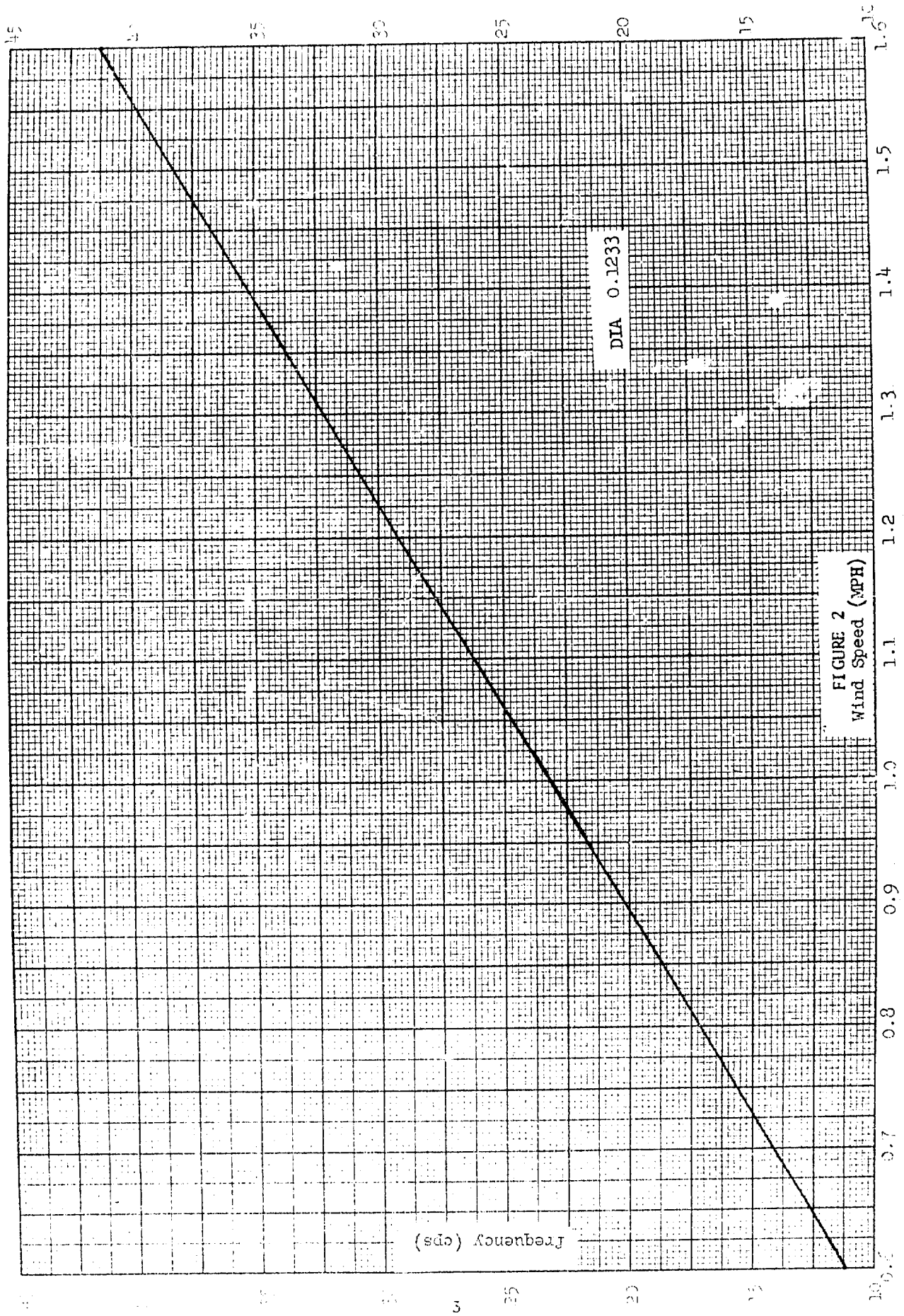


FIGURE 1



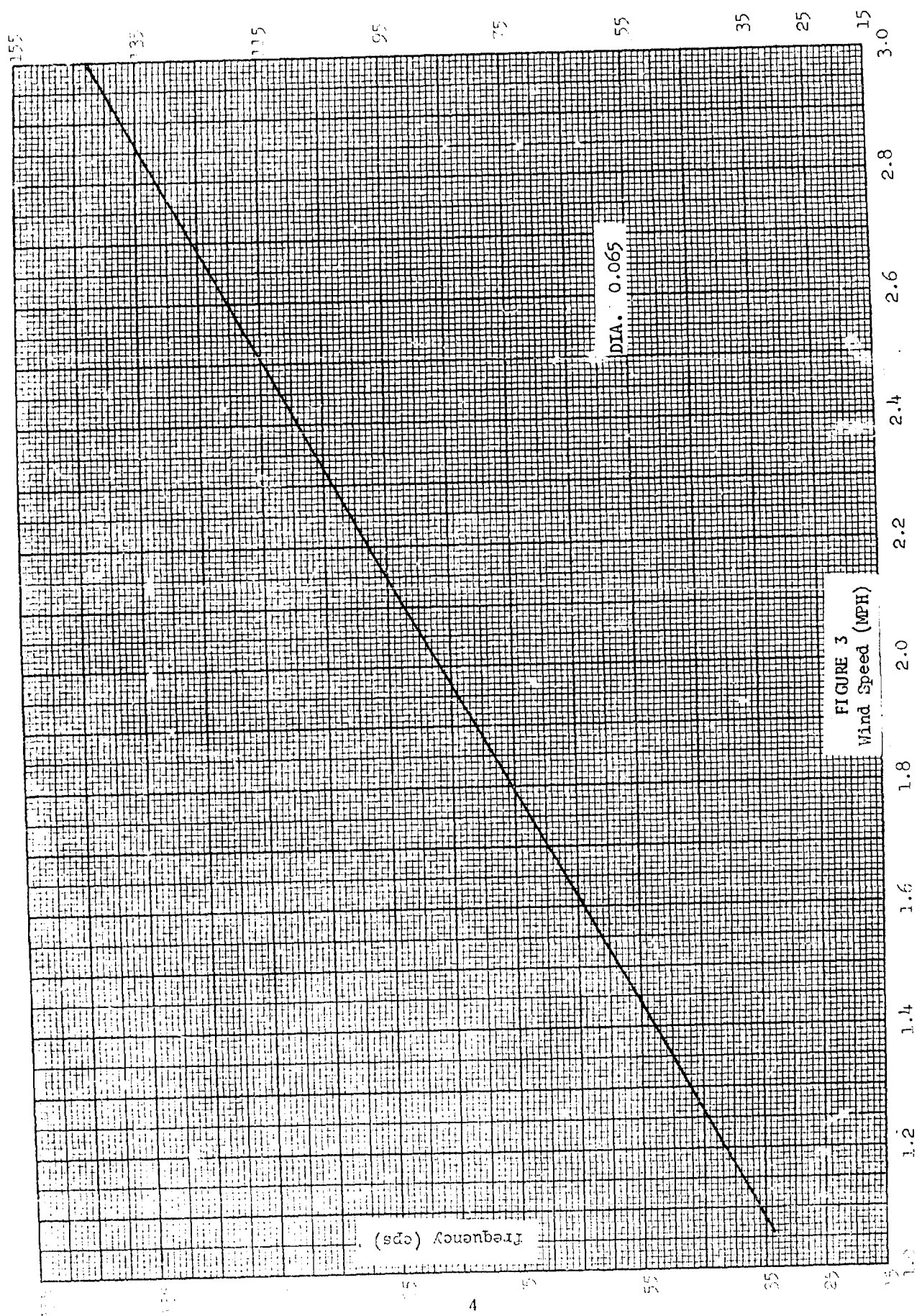
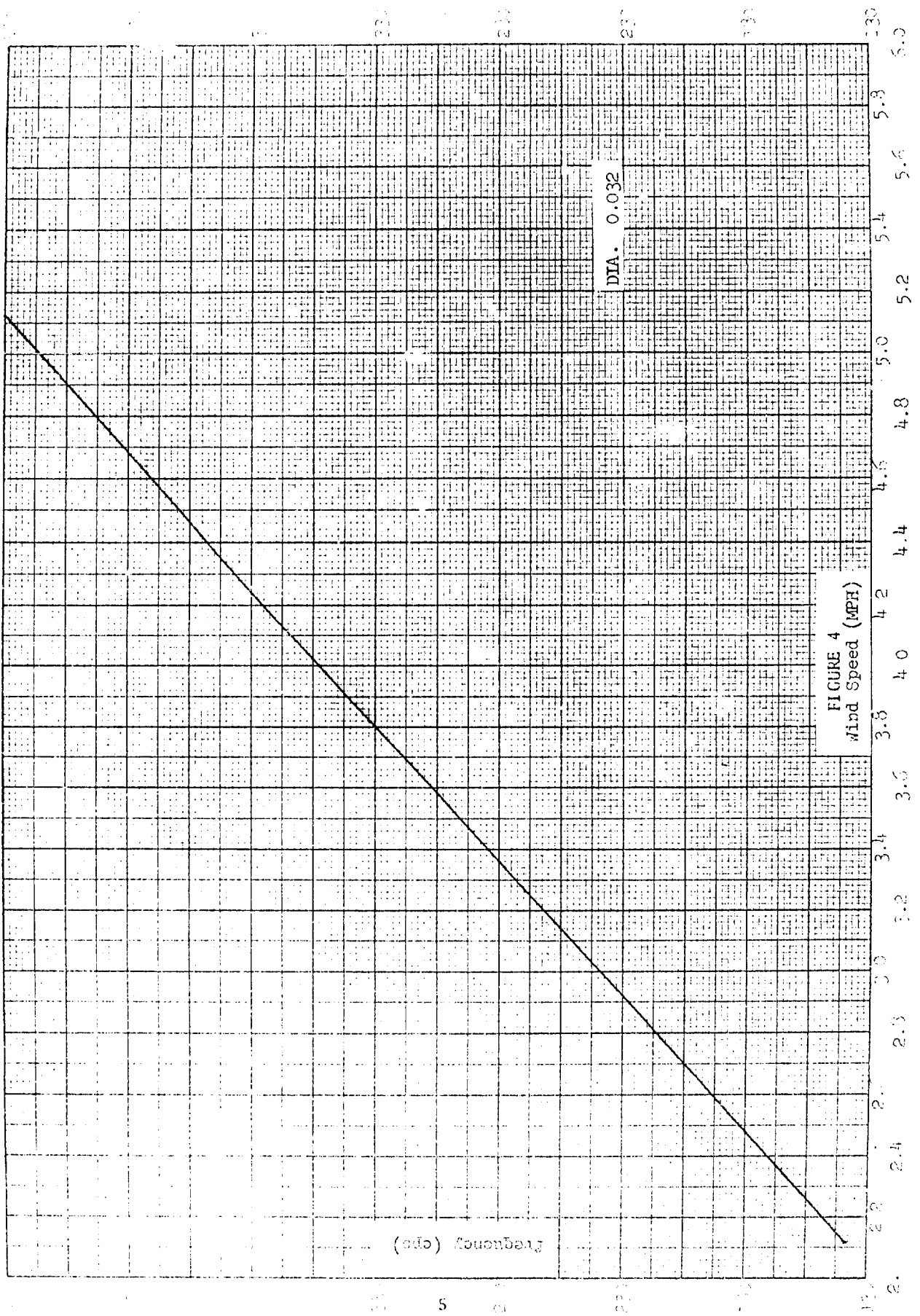
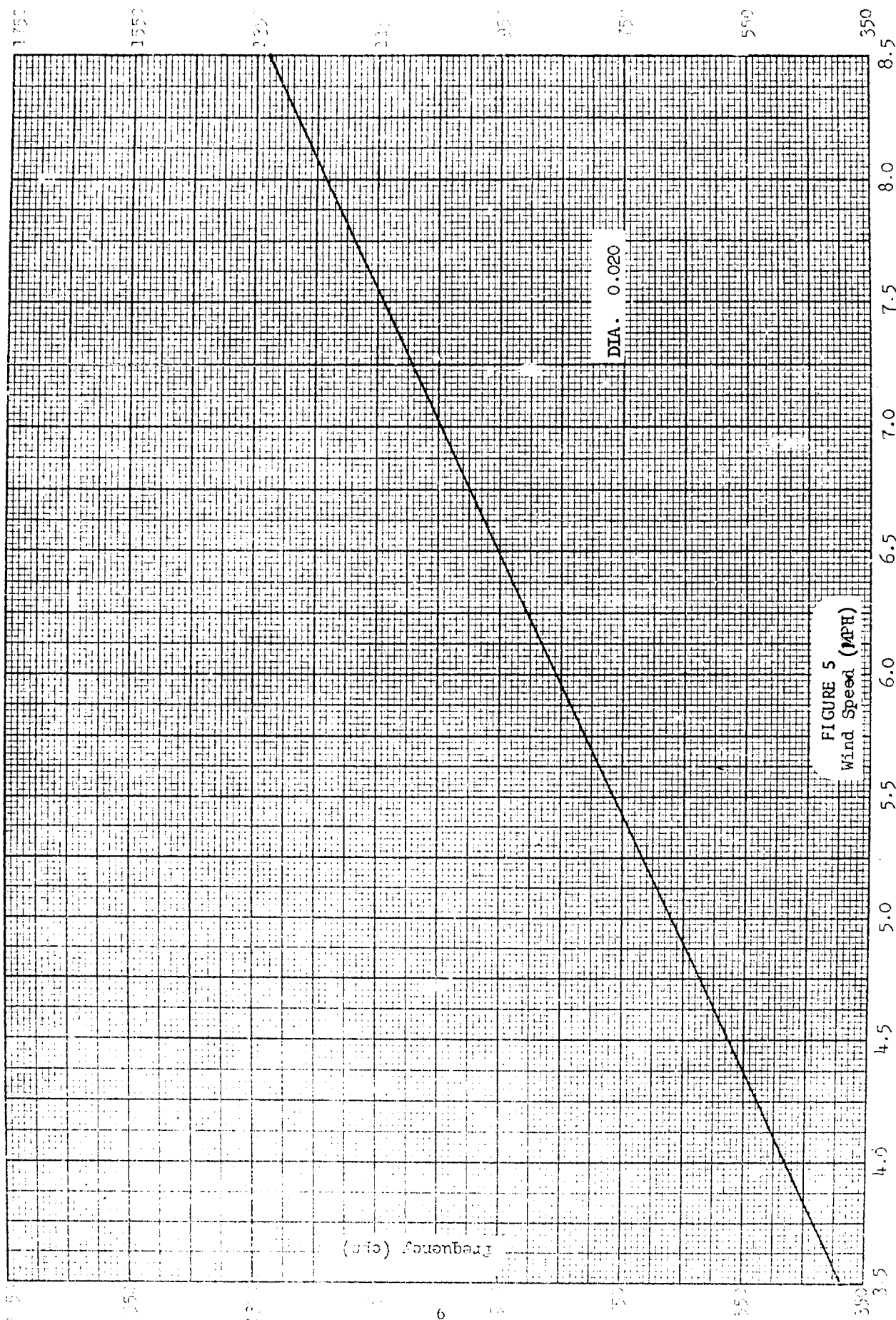


FIGURE 3
Wind Speed (MPH)





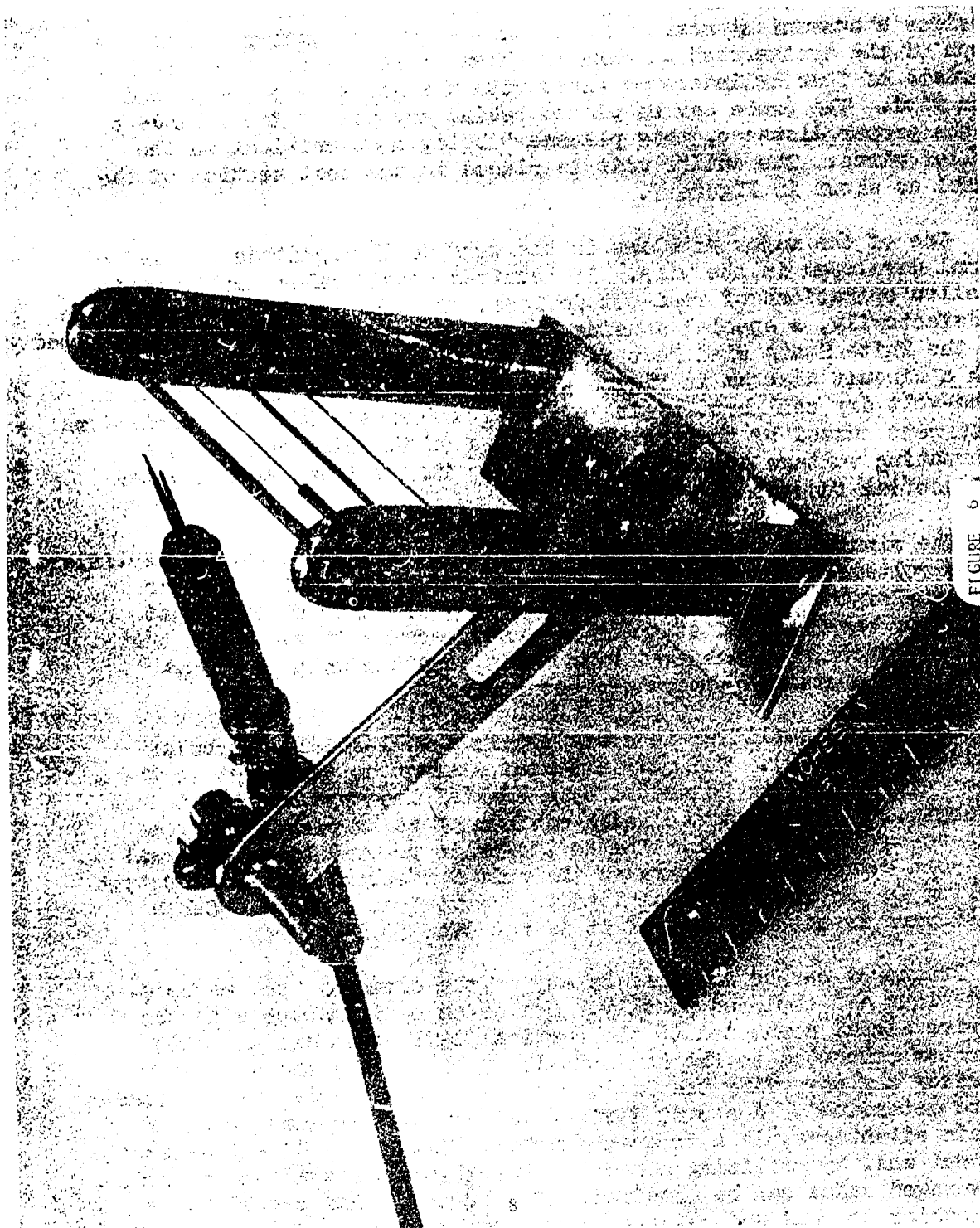
To utilize the effect discussed, a read-out sensor is needed. Past experimentation and development has demonstrated that the periodic cooling of a heated wire placed in the wake of the cylinder (Figure 1) provides a convenient means of sensing the eddy frequency. A photograph of the system used at WSMR is shown in Figure 6. The assembly consists of four cylinders or wires with the hot wire probe placed down wind. The probe can be placed behind any one of the cylinders at the proper distance, this placement being most critical on the smaller wires. The entire unit is placed in the test section of the tunnel as shown in Figure 7.

One of the major problems is the very small magnitude of the signal developed in the wire. It requires considerable amplification to allow operations of read-out devices. To achieve this amplification satisfactorily, a special sensing and amplifying system has been developed for the White Sands Wind Test Facility. This is shown in Figure 8 with a circuit diagram in Figure 9. The sensing wire is heated by a three-volt dry cell battery in series with Resistor R_1 . The variations in current caused by the periodic cooling of the wire result in an alternating voltage appearing across R_1 . This voltage approximates a sinusoidal function.

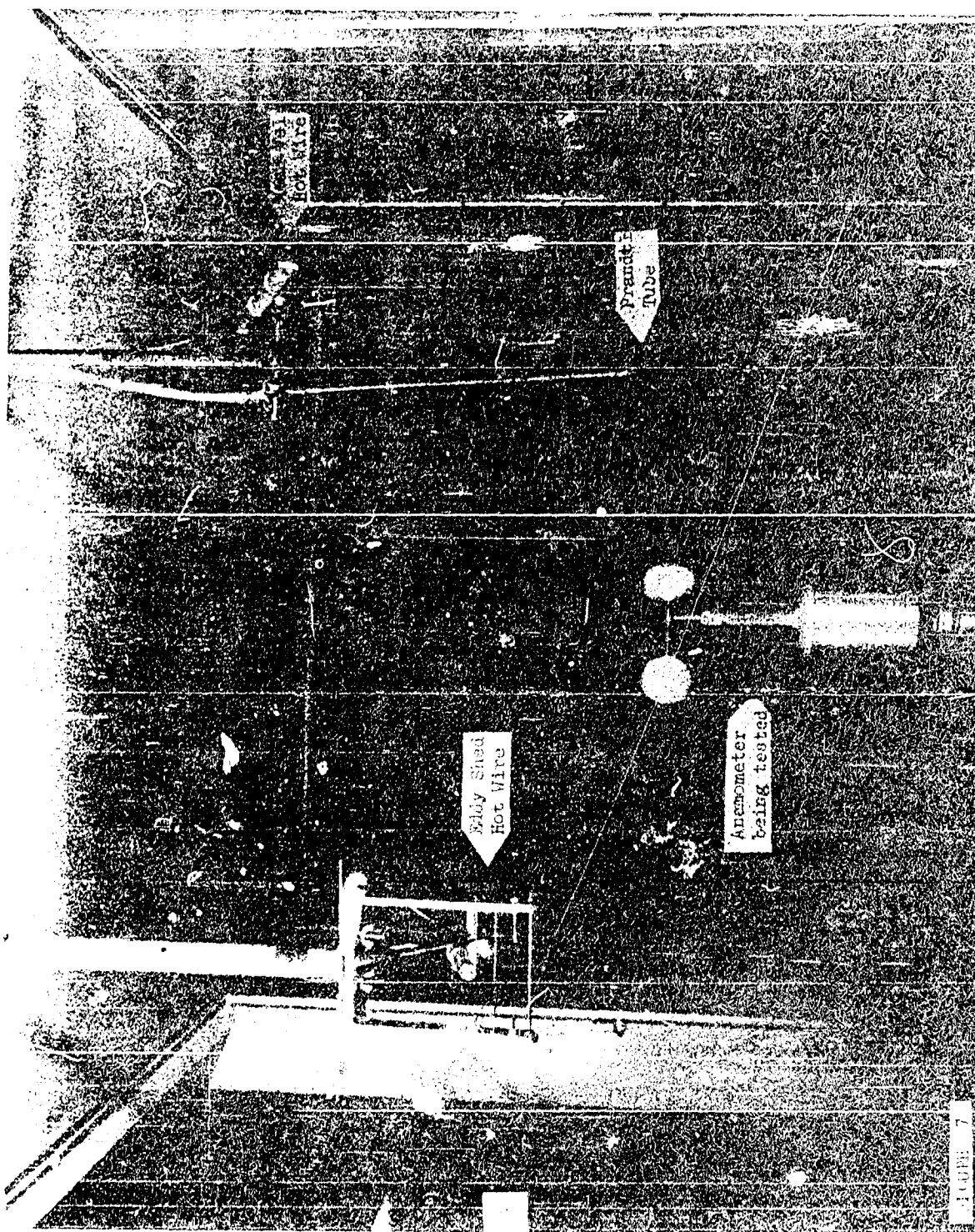
The minute voltage is coupled into a two-stage transistor amplifier with a voltage gain of over 7000 (77 db) and sufficient output to drive any of the read-out devices required. It can be noted that transistor base stabilization is not used because it was found that higher gain could be achieved without it, and the unit is always operated in a stable temperature environment.

The entire amplifier is contained in a well-shielded tubular housing (Figure 10). The only external element on the input is the heated wire and it is connected by a coaxial lead not over 40 inches in length. This layout assured a minimum of stray pickup and good input-to-output isolation. The amplifier is powered by an external nine-volt battery which operates the unit for several months. Output coupling is through a coaxial lead to the readout devices. Cable length here is not critical if it is not over 50 feet.

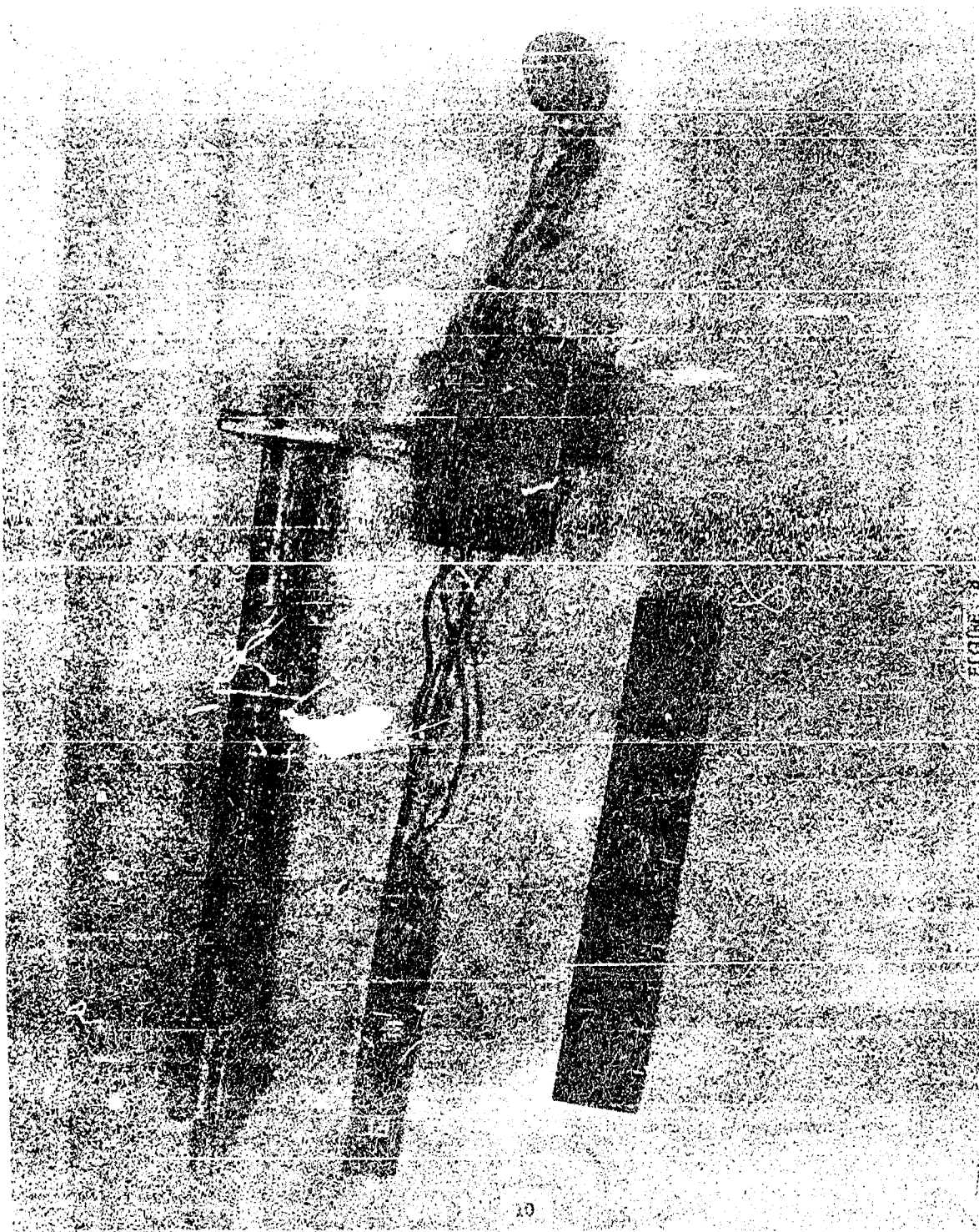
Frequency can be measured by any of the commonly used methods. Two devices are employed locally. One is an oscilloscope with the hot wire signal connected to the vertical deflection and an audio generator connected to the horizontal. By adjusting the generator frequency and observing the Lissajous pattern, the eddy shed frequency can be determined. A second device, and one that appears to offer certain advantages, is a frequency meter. It gives a direct decimal read out and, by utilizing a sample time of greater than one second, an averaged value can be obtained. This approach has proved to be much easier to read and results in improved accuracy of the readings.

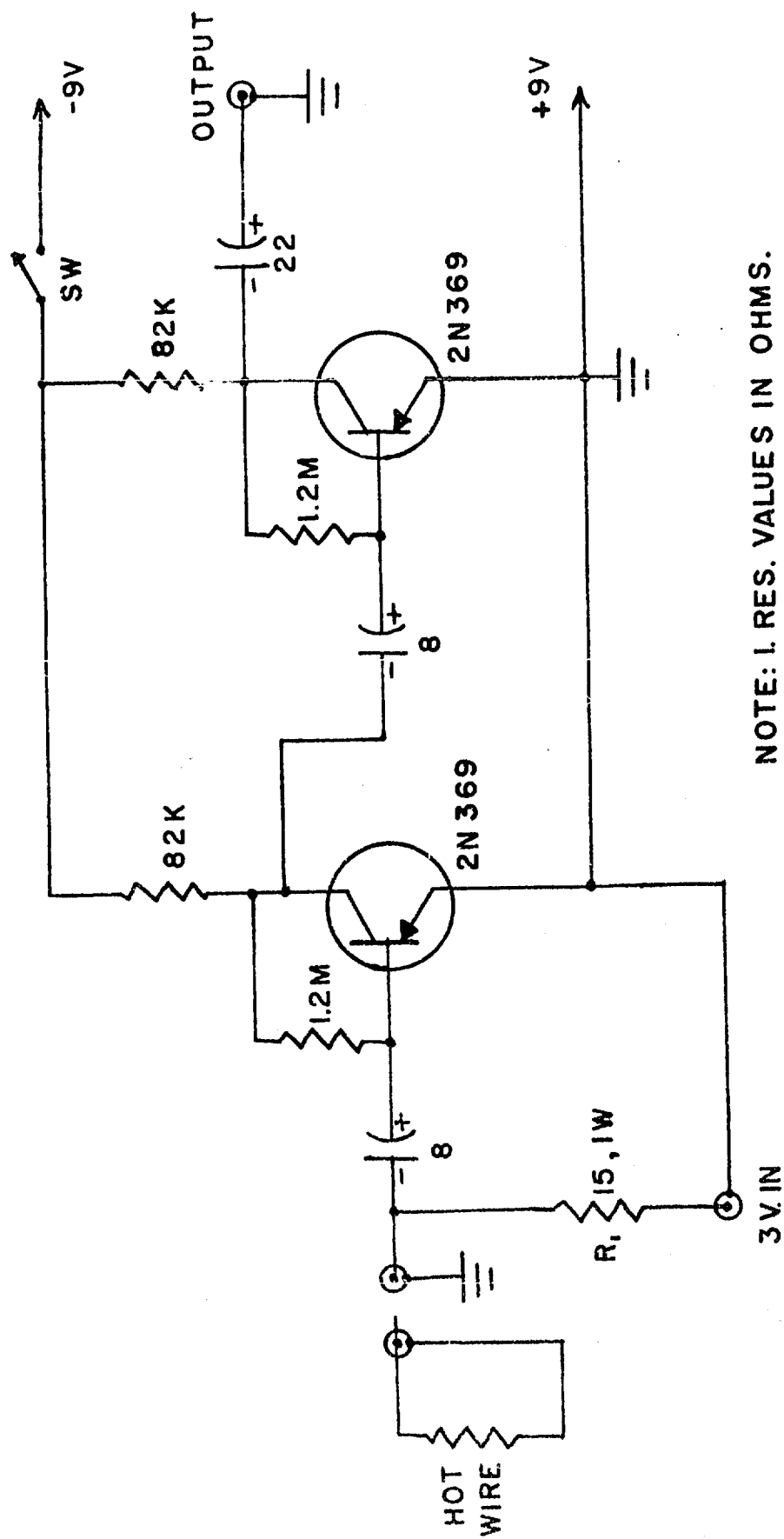


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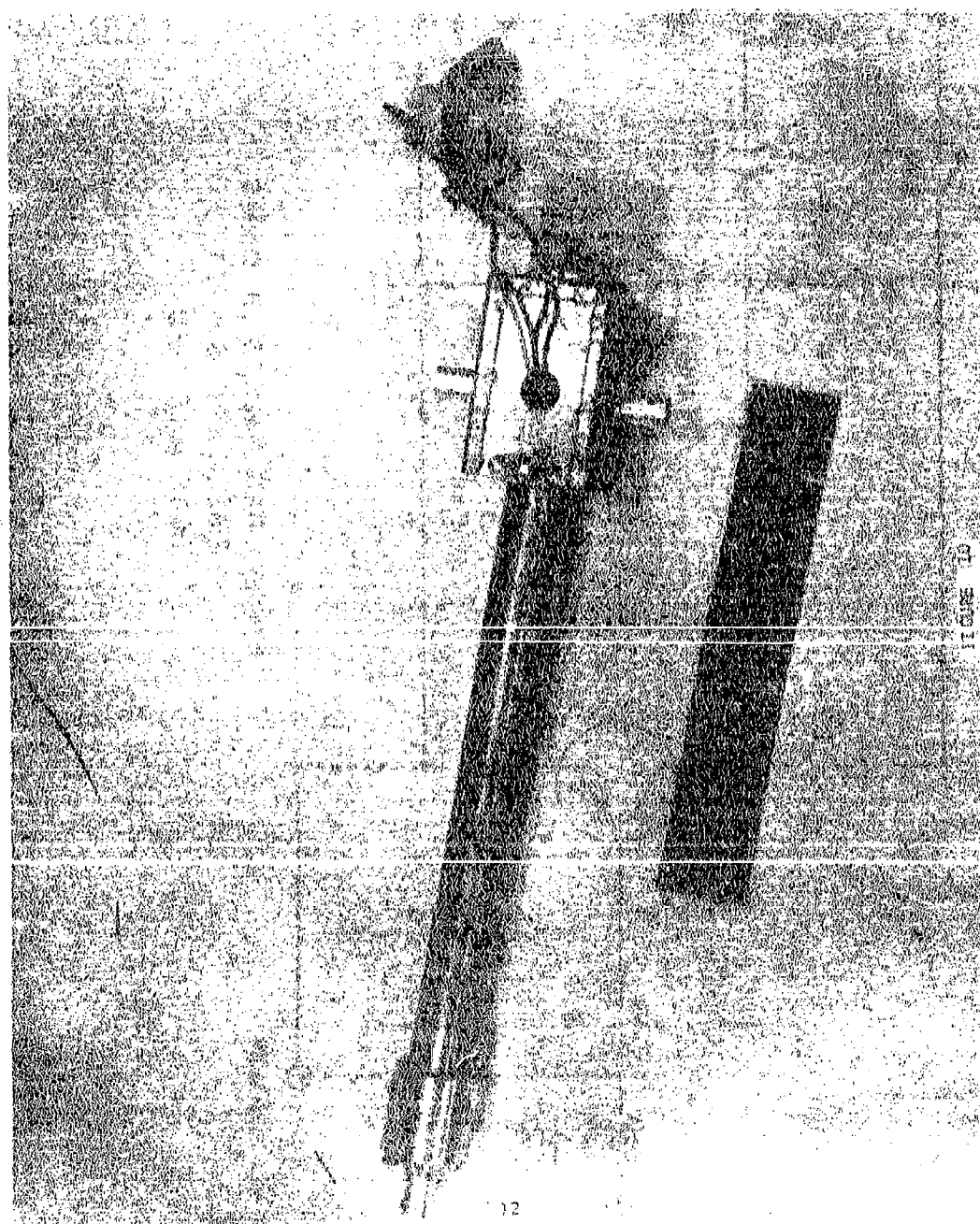
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NOTE: 1. RES. VALUES IN OHMS.
 2. RES. ARE .5 WATT.
 3. CAP. ARE MFD.

AMPLIFIER FOR EDDY SHED HOT WIRE ANEMOMETER SYSTEM - FIGURE 9



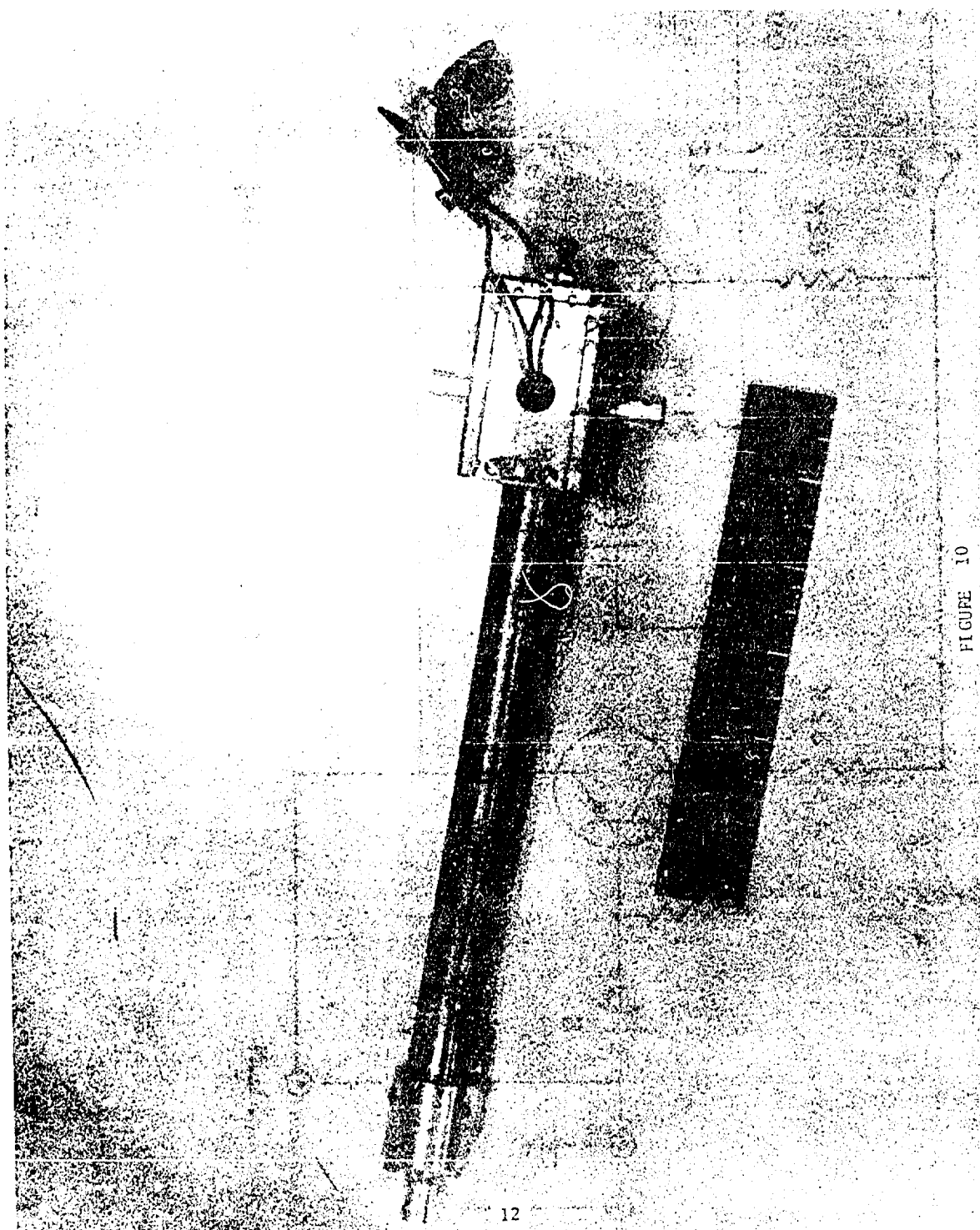


FIGURE 10


RESULTS


The system described has been in use for almost two years in the White Sands Wind Test Facility and has proved to be the only reliable method of measuring the low wind velocities. Stray signal pickup has not been encountered, and signal output has been ample in the required range. Limitations on the useable wind velocity ranges are primarily due to two conditions. First, at velocities over about 12 miles per hour, the required cylinder diameter is too small to produce eddys of measurable amplitude. Second, at velocities below about 0.4 mile per hour the wind movement around the larger cylinder becomes so random that readings are no longer possible. These conditions do not limit the use of the tunnel because the threshold velocity of most of the wind instrumentation tested is above about 0.7 mile per hour. In addition, above 10 miles per hour, a prandtl tube and a mean velocity hot wire provide accurate measurements.

U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT ACTIVITY
WHITE SANDS MISSILE RANGE
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Approval. Technical Report ERDA-185 has been reviewed and approved for publication.


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WHITE SANDS MISSILE RANGE
NEW MEXICO

SEPTEMBER 1964

1. Technical Report ERDA-185 has been prepared under the supervision of the Environmental Sciences Directorate and is published for the information and guidance of all concerned.

2. Suggestions or criticisms relative to the form, contents, purpose, or use of this publication should be referred to the Commanding Officer, U. S. Army Electronics Research and Development Activity, ATTN: SELWS-M, White Sands Missile Range, New Mexico.

FOR THE COMMANDER:


L. W. ALBROW
Major, AGC
Adjutant

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<p>ACCESSION NR</p> <p>Army Electronics Research and Development Activity, Environmental Sciences Directorate, White Sands Missile Range, New Mexico.</p> <p>STUDY SHEET EOT WIND ANSWER, By Roy I. Glass, Jr. EDMA-185, September 1964, 16 pp incl illus.</p> <p><u>UNCLASSIFIED REPORT</u></p> <p>This paper presents the need for an accurate low wind speed measuring system for the White Sands Missile Range Wind Instrument Test Facility. It describes a device that has been installed in the facility and which operates on the principle of periodic eddy shedding on the down-wind side of a cylinder. Also presented is the special readout system developed for the device.</p>	<p>UNCLASSIFIED</p> <p>1. Wind Tunnel</p> <p>2. Anemometer</p> <p>3. Wind Speed</p> <p>4. Eddy Shedding</p> <p>Qualified requesters may obtain copies of this report from:</p> <p>Defense Documentation Center Cameron Station Alexandria, Virginia</p>	<p>ACCESSION NR</p> <p>Army Electronics Research and Development Activity, Environmental Sciences Directorate, White Sands Missile Range, New Mexico.</p> <p>STUDY SHEET EOT WIND ANSWER, By Roy I. Glass, Jr. EDMA-185, September 1964, 16 pp incl illus.</p> <p><u>UNCLASSIFIED REPORT</u></p> <p>This paper presents the need for an accurate low wind speed measuring system for the White Sands Missile Range Wind Instrument Test Facility. It describes a device that has been installed in the facility and which operates on the principle of periodic eddy shedding on the down-wind side of a cylinder. Also presented is the special readout system developed for the device.</p>	<p>UNCLASSIFIED</p> <p>1. Wind Tunnel</p> <p>2. Anemometer</p> <p>3. Wind Speed</p> <p>4. Eddy Shedding</p> <p>Qualified requesters may obtain copies of this report from:</p> <p>Defense Documentation Center Cameron Station Alexandria, Virginia</p>
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